

Language Development, Critical Periods in

Intermediate article

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CONTENTS

Introduction

Evidence for a critical or sensitive period for language acquisition

Questions concerning a critical or sensitive period for language acquisition

First language acquisition typically occurs in infancy and early childhood. An important question concerns whether the acquisition of a first or a second language shows a critical or sensitive period: that is, whether acquisition displays a normal course and leads to full proficiency in the language only when it begins early in life.

INTRODUCTION

In many species, including humans, important and species-typical behaviors develop through an intricate combination of innate and experiential factors. One hallmark of such systems is the appearance of a critical or sensitive period for normal development.

A critical period is a maturational time period during which some crucial experience will have its peak effect on development or learning, resulting in normal behavior attuned to the particular environment to which the organism has been exposed. If the organism is not exposed to this experience until after this time period, the same experience will have only a reduced effect, or in extreme cases may have no effect at all. Well-studied examples of species-typical behaviors showing peak plasticity within a critical or sensitive period include the identification of a species member as an attachment object (called 'imprinting') in ducks and birds, the acquisition of the species mating song by finches and sparrows, and the spatial tuning of auditory localization in barn owls. In contrast, in other domains and systems, there may be plasticity uniformly throughout life (open-ended learning), or plasticity may increase with age as experience or higher-level cognitive skills increase.

In his seminal book *Biological Foundations of Language*, Eric Lenneberg (1967) hypothesized that human language acquisition was an example of biologically constrained learning, and that it was normally acquired during a critical period,

beginning early in life and ending at puberty. Outside of this time period, he suggested, language could be acquired only with difficulty or by a different learning process. He also suggested a neural mechanism for this developmental change: he hypothesized that the critical period for language acquisition ended with the establishment of cortical lateralization of function, as the brain reached its mature organization in late puberty.

Since the time of Lenneberg's book, an extensive research literature has asked whether there is indeed a critical or sensitive period for human language acquisition. These studies have provided strong support for the existence of such a critical or sensitive period (particularly for acquiring the phonology and grammar of language), though not for Lenneberg's specific hypothesis about the relationship between lateralization and the end of the critical period.

The term 'critical period' is sometimes used when there is an abrupt decline in plasticity and no residual plasticity after this period is over, whereas the term 'sensitive period' is used when there is a more gradual decline and some (reduced) plasticity remaining throughout life. However, recent research has shown that most critical periods show more gradual offsets and more complex interactions between maturational and experiential factors than the original concept of a critical period had anticipated. The terms are therefore often used interchangeably, as will be done in the present article.

EVIDENCE FOR A CRITICAL OR SENSITIVE PERIOD FOR LANGUAGE ACQUISITION

A number of lines of research, both behavioral and neural, suggest that there is a critical or sensitive period for language acquisition. Case studies of

individual feral or abused children, isolated from exposure to their first language until after puberty, have shown extreme deficits in phonology, morphology, and syntax resulting from this deprivation. The best studied of these cases is a girl named Genie, who was followed closely for a number of years after her discovery and placement in a normal linguistic environment at age 13 (Curtiss, 1977). While Genie did successfully acquire some English after puberty, her phonology was abnormal, and her control over English syntax and morphology was limited to only the simplest aspects of the language.

However, in cases of isolated children, general physical and cognitive status may be a concern. In studies of populations of normal individuals, one can systematically examine proficiency in relation to age of linguistic exposure without concern about the physical status of the learning brain. These studies show a strong relationship between the age of exposure to a language and the ultimate proficiency achieved in that language (Johnson and Newport, 1989; Krashen *et al.*, 1982; Long, 1990; Newport, 1990), though typically with many fewer extreme deficits in adult learning than those found in the case studies of isolated children. Learning during the first months or year of exposure may show an advantage for adult learners, particularly in the acquisition of vocabulary and the speed of using certain complex sentence forms; however, long-term outcome clearly favors those who start learning the language during childhood. Peak proficiency in the language, in control over the sound system as well as the grammatical structure, is displayed by those whose exposure to that language begins in infancy or very early childhood. Such early learners show not only flawless control over the accent and rhythm of the language but also full and productive control over the syntax and morphology. With increasing ages of exposure there is a decline in average proficiency, beginning as early as ages 4 to 6 and continuing until proficiency plateaus for adult learners (Johnson and Newport, 1989; Newport, 1990). Learners exposed to the language in adulthood show, on average, a lowered level of performance in many aspects of the language, though individual variation also increases with age (Johnson and Newport, 1989), and some individuals may approach the proficiency of early learners (Birdsong, 1992).

These effects have been shown for both first and second languages, and for measures of proficiency including degree of accent, production and comprehension of morphology and syntax,

grammaticality judgments for morphology and syntax, and syntactic processing speed and accuracy. For example, Johnson and Newport (1989) have shown that Chinese or Korean immigrants who move to the United States and become exposed to English as a second language show strong effects of their age of exposure to the language on their ability to judge its grammatical structure many years later, even when the number of years of exposure is matched. These effects are not due merely to interference of the first language on the learner's ability to acquire the second language: deaf adults, acquiring American Sign Language as their primary language, show effects of age of exposure on their grammatical skills in ASL as much as 50 years later, even though they may not control any other language with great proficiency (Newport, 1990; Mayberry and Eichen, 1991).

While there are effects of age of acquisition on both first and second languages and on both spoken and signed languages, an important question is how these effects compare. Does the acquisition of a language early in life reduce the effects of age on later language learning? This question has been examined by comparing hearing and deaf individuals' acquisition of English or American Sign Language as either a first or a second language, and (if as a second language) after early exposure to either a spoken or a signed language (Mayberry *et al.*, 2002). The results show that age of first language onset has a significant effect, while language modality does not: late first language acquisition results in lower performance than does late second language acquisition, regardless of whether the languages in question were spoken or signed. According to one recent finding, even overhearing a language during early childhood, without producing it or hearing it again for many years, can result in learning to pronounce that language with a more native accent as an adult (Au *et al.*, 2002).

However, age of exposure does not affect all aspects of language learning equally. The acquisition of vocabulary and semantic processing occur relatively normally in late learners. Critical period effects thus appear to focus on the formal properties of language (phonology, morphology, and syntax) and not the processing of meaning. Even within the formal properties of language, though, various aspects of the language may be more and less dependent on age of language exposure. For example, late learners acquire the basic word order of a language relatively well, but more complex aspects of grammar show strong effects of late

acquisition (Johnson and Newport, 1989; Newport, 1990). Further research is needed to characterize the structures that do and do not show strong effects of age of learning.

Age of exposure also affects the way language is represented in the brain, with similarities between the behavioral and neural effects. PET (Positron Emission Tomography), fMRI (functional magnetic resonance imaging), and ERP (event-related potential) studies all show strong left hemisphere activation for processing the native language, in bilinguals as well as monolinguals. However, when second languages are learned after age seven, the regions and patterns of activation are partially or completely nonoverlapping with those for the native language. Neural organization for late-learned languages is less lateralized and, like proficiency itself, displays a high degree of variability from individual to individual (Perani *et al.*, 1996; Weber-Fox and Neville, 1996; Kim *et al.*, 1997). The few studies that have observed early bilinguals or highly proficient late bilinguals report congruent results for native and second languages (Perani *et al.*, 1998), though more refined techniques in the future might be expected to show neural differences whenever there are behavioral differences.

As with linguistic behavior, there is considerable specificity in these neural effects. In particular, age of acquisition appears to have more pronounced effects on grammatical processing and its representation in the brain than on semantic processing (Weber-Fox and Neville, 1996). When native speakers of English, respond to the appropriateness of open-class content words, ERP components distributed over the posterior regions of both hemispheres; and these same patterns appear in Chinese-English bilinguals who have acquired English as late as age 16. In contrast, when judging English syntactic constructions or responding to the placement of closed class function words in sentences, only early learners show the characteristic anterior left hemisphere ERP components; learners with delays of even 4 years show significantly more bilateral activation (Weber-Fox and Neville, 1996). Similar effects appear for signed languages (Neville *et al.*, 1997).

Taken together, these results provide fairly strong evidence for a critical or sensitive period in acquiring the phonological and grammatical patterns of the language and in organizing the neural mechanisms for handling these structures in a proficient way. Nonetheless, the question of whether there is a critical period for language acquisition continues to be controversial.

QUESTIONS CONCERNING A CRITICAL OR SENSITIVE PERIOD FOR LANGUAGE ACQUISITION

Several questions have been raised about whether these age effects represent the outcome of a critical or sensitive period, or whether they might arise from variables correlated with age but not with maturation. One set of questions concerns whether the behavioral function has the correct shape for a critical or sensitive period. Must a critical period involve an abrupt decline and a total loss of plasticity at the end? Some investigators have argued that, in order to support a critical period hypothesis, age effects must coincide with the onset of puberty (though neural maturation continues throughout the teenage years and does not cease at ages 12 to 13). Other investigators have suggested that, if there were a critical or sensitive period for acquisition, no adult learners should achieve native proficiency. Finally, investigators have noted that it is difficult to distinguish a critical or sensitive period for learning from an interference effect.

However, many of the strong or absolute characteristics expected or demanded by these investigators are not true of critical or sensitive periods in other domains. Critical or sensitive periods in most behavioral domains involve gradual declines in learning, with some (reduced but not absent) ability to learn, and greater individual variation, in mature organisms. Critical periods in other domains also exhibit more learning during the waning portion of the critical period if the organism is presented with extremely salient or strongly preferred stimuli, or with learning problems similar to those experienced early in life. It should therefore not be surprising that a critical period for language in humans would show some continuing ability to learn, with individual variation, during adulthood. If such complex phenomena are routinely found within critical periods in other domains, they should also be expected for language learning.

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Language Disorders

Intermediate article

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CONTENTS

Introduction

Components of communication

Linguistically manifested disorders that are not language disorders

Congenital and developmental pathologies that are linguistic

Acquired linguistic pathologies

Relating brain and language

Language disorders (as distinct from communicative deficits) provide an important tool for research on brain–language relations.

INTRODUCTION

The neurosciences seek to understand how the healthy brain works. What, then, is the reason to study it in disease? Language as a cognitive capacity is investigated intensively; yet under what

guise do disturbances to language and speech become a topic for scientific inquiry? One undisputed goal is remedial: we study pathologies in order to cure them. Yet there is another, less obvious goal: We would like to study language diseases as a vehicle for biologically-based componential analyses of the human language faculty. Deficit analyses have been an extremely valuable research tool for over a century, providing a critical testing ground for theories of brain–language relations.